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The Transmission of Monetary Policy and Technology Shocks in the Euro Area*

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Abstract

This paper analyzes the response of a set of euro area macroeconomic variables to monetary policy and technology shocks based on structural VARs. The data set runs from 1970Q1 until 2006Q4 and includes a novel long-run series for hours worked per capita in the euro area. We find that real macroeconomic variables follow a hump-shaped response after monetary policy shocks and jump on impact after technology shocks. We also provide evidence that hours worked fall after a positive technology shock. These conclusions are robust to different sample periods and specifications of the variables.

JEL Classification: E32, E52.

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1 Introduction

This paper analyzes the dynamic response of a set of euro area macroeconomic variables to monetary policy and technology shocks using structural VAR models. Our results build on previous work for the euro area, namely Peersman and Smets (2003), who only identify monetary policy shocks, and Peersman and Straub (2004), who estimate both monetary and technology shocks using model-based sign restrictions. In contrast to those papers, we identify both shocks simultaneously by imposing theoretically-consistent restrictions both in the short-run and the long-run, in line with Altig, Christiano, Eichenbaum and Linde (2005).

The identification of impulse response functions based on structural VAR models aims not only at assessing the properties of the data but also at understanding the set of shocks and frictions that should be incorporated in dynamic general equilibrium models. An important debate in the literature is whether Galí's conclusions, that positive technology shocks induce a short-run decline in hours worked, is robust to different specifications. Several arguments have been traded in this context, with Basu, Fernald and Kimball (2004), Francis and Ramey (2005), and Galí (2004) broadly supporting Gali's (1999) original claim and Christiano, Eichenbaum and Vigfusson (2004) and Uhlig (2004) presenting a critical view of these conclusions[1]. We contribute to this debate by building a novel long-run series of hours worked per capita in the euro area and incorporating it in the VAR, which also includes measures of labour productivity,

*The views expressed in this paper are of the authors and do not necessarily those of Banco de Portugal. We thank the comments of two anonymous referees and participants at the Banco de Portugal's internal seminar. Corresponding author's email: jmsousa@bportugal.pt

[1]See also Erceg, Guerrieri and Gust (2005) for an assessment of the reliability of identifying technology shocks using long-run restrictions on a VAR.

inflation, the consumption to output ratio, the investment to output ratio, capacity utilization, the productivity to real wage ratio, the interest rate and M1 velocity. The sample runs from 1970Q1 until 2006Q4.

Several of our main conclusions are worth anticipating. First, in line with the results for the US presented in Altig et al. (2005), we find that real variables in the euro area follow a hump-shaped pattern after a monetary policy shock and jump on impact after a technology shock. Second, we find that per capita hours worked fall in the euro area after a positive technology shock, in line with the conclusions of Galí (2004) for the euro area using a measure of employment. It should be noted that we conclude from our analysis that per capita hours are non-stationary in the sample period. This conclusion is particularly important, given that, as in Christiano et al. (2004), the response of hours worked to a neutral technology shock depends on the evidence regarding the stationarity of per capita hours. Third, both conclusions above are robust to different sample periods and to different specifications of the variables. Finally, we show that technology shocks explain a significant part of the fluctuations of output, hours worked and wages in the euro area, while monetary policy shocks have a substantial contribution to the variations in the short-term interest rate.

The remainder of the paper is organized as follows. Section 2 presents the strategy to identify the shocks. Section 3 describes the data and their main empirical properties. Section 4 discusses the main results and section 5 undertakes several robustness checks. Section 6 presents the historical contribution of the shocks to the variance of the variables in the VAR. Section 7 concludes.

2 Identification of shocks

In the identification of the technology and the monetary policy shocks, we follow the methodology of Altig et al. (2005). The analysis is based on the following reduced-form VAR,

$$Y_t = \eta + B\left(L\right)Y_{t-1} + u_t,\ Eu_t u_t^{'} = V \tag{1}$$

where $B(L)$ is a polynomial of order q in the lag operator, L, u_t is the vector of the one-step-ahead forecast errors to Y_t. The Y_t vector is defined as,

$$\underbrace{Y_t}_{9\times1} = \begin{pmatrix} \Delta\ln\left(GDP_t/\text{Hours}_t\right) \\ \ln\left(\text{Hours}_t\right) \\ \Delta\ln\left(GDP\ \text{deflator}_t\right) \\ \ln\left(C_t/GDP_t\right) \\ \ln\left(I_t/GDP_t\right) \\ \ln(\text{Capacity Utilisation}_t) \\ \ln\left(GDP_t/\text{Hours}_t\right) - \ln\left(W_t/P_t\right) \\ \text{Interest Rate}_t \\ \ln\left(GDP\ \text{deflator}_t\right) + \ln\left(GDP_t\right) - \ln\left(M1_t\right) \end{pmatrix}$$

Starting with the monetary policy shocks, we identify monetary policy shocks as deviations from a policy rule that is assumed to be followed by policymakers (see Christiano, Eichenbaum and Evans (1999)):

$$R_t = f(\Omega_t) + \varepsilon_{Rt}$$

where R_t is the interest rate, f a linear monetary policy rule, which is a function of the information set Ω_t available to the policymakers. ε_{Rt} is the monetary policy shock.

The identification of the monetary policy shocks is achieved by assuming that ε_{Rt} is orthogonal to the information set Ω_t. In addition, we require that the only date t variables in the information set are productivity, measures of economic activity (hours, capacity utilization), wages and inflation. The introduction of the monetary aggregates in the system allows the identification of money demand shocks. We assume that the central bank does not react contemporaneously to money velocity shocks.

In identifying the technology shock, we follow much of related literature by imposing the restriction that only technology shocks can affect labour productivity in the long run (this restriction on VARs has been originally proposed by Galí (1999)). In implementing it, we pursue the methodology advocated by Shapiro and Watson (1988). The structural representation of the VAR models we use can be written as:

$$A_0 Y_t = A(L) Y_{t-1} + e_t, e_t = \begin{bmatrix} \underbrace{e_{zt}}_{(1\times 1)} \\ \underbrace{e_{1t}}_{(6\times 1)} \\ \underbrace{e_{R_t}}_{(1\times 1)} \\ \underbrace{e_{2t}}_{(1\times 1)} \end{bmatrix}$$

where the structural shocks, e_t, which are unobservable, are assumed to be mutually independent and related linearly to the one-step-ahead forecast errors, u_t:

$$u_t = C e_t, \qquad E e_t e_t^{'} = I.$$

The parameters of the structural form are therefore linked to those of the reduced form by:

$$C = A_0^{-1}, B\left(L\right) = A_0^{-1} A\left(L\right) \tag{2}$$

where the first and eighth columns of C are the objects we need to uniquely identify in order to compute the impulse responses pertaining to a technology and monetary shocks, respectively. It turns out that we need to estimate A_0 in order to estimate the technological and monetary shocks as well as their dynamic effects on Y_t. The identifying restrictions laid down above impose the following structure on the matrix A_0:

$$A_0 = \begin{bmatrix} \underbrace{A_0^{1,1}}_{(1\times 1)} & \underbrace{A_0^{1,2}}_{(1\times 1)} & \underbrace{A_0^{1,3}}_{(1\times 6)} & \underbrace{0}_{(1\times 1)} & \underbrace{0}_{(1\times 1)} \\ \underbrace{A_0^{2,1}}_{(6\times 1)} & \underbrace{A_0^{2,2}}_{(6\times 1)} & \underbrace{A_0^{2,3}}_{(6\times 6)} & \underbrace{0}_{(6\times 1)} & \underbrace{0}_{(6\times 1)} \\ \underbrace{A_0^{3,1}}_{(1\times 1)} & \underbrace{A_0^{3,2}}_{(1\times 1)} & \underbrace{A_0^{3,3}}_{(1\times 6)} & \underbrace{A_0^{3,4}}_{(1\times 1)} & \underbrace{0}_{(1\times 1)} \\ \underbrace{A_0^{4,1}}_{(1\times 1)} & \underbrace{A_0^{4,2}}_{(1\times 1)} & \underbrace{A_0^{4,3}}_{(1\times 6)} & \underbrace{A_0^{4,4}}_{(1\times 1)} & \underbrace{A_0^{4,5}}_{(1\times 1)} \end{bmatrix}$$

As seen above, we assume that in the short-run real economic activity and prices do not react contemporaneously to monetary policy shocks or to shocks to money velocity, which explains the zero restrictions on the first seven rows of the two last columns of the A_0 matrix above. This restriction stems from the empirically grounded assumption that in the short-term real variables do not respond significantly to nominal shocks. We thus follow a long tradition in monetary economics (going back to Friedman (1961)) in assuming the existence of lags in the transmission of monetary policy. As for the restriction that the interest rate does not to react contemporaneously to velocity shocks we follow Larry Christiano and Evans (2005). The justification for this restriction is that it is necessary to make the VAR consistent with the general equillibrium model of Larry Christiano and Evans (2005) which we take as our reference. As monetary policy may still react to past velocity shocks this restriction is not very binding. Finally, the restriction that technology shocks (e_{zt}) are the only shocks having a non-zero effect on labour productivity in the long-run implies that the matrix $A_0 - A(1)$ has all zeros in the first row except in the (1,1) element.

3 Data

3.1 Description

The data used in the paper refer to an aggregate of twelve euro area member states for the period from the first quarter of 1970 to the last quarter of 2006[2]. For periods prior to 1999, the data correspond to an aggregation of the available country series. The use of aggregated euro area data is now standard in the literature, even though it has the drawback of assuming that before 1999 the euro countries behaved as if they formed a monetary union, which was obviously not the case. Recent examples of the use of similar aggregated data in related studies are the VAR studies of Peersman and Smets (2003) and Peersman and Straub (2004) or the euro area-wide models of Fagan, Henry and Mestre (2001), Smets and Wouters (2003) and Günter Coenen and Straub (2007). Note that, to some extent, the robustness tests in section 5, namely the analysis of the stability of the responses over time, should be able to detect potential problems related to the aggregation of the country series before 1999.

As far as possible we used official statistical sources, such as the Eurostat, the ECB, the European Commission and the OECD. However, euro area series at a quarterly frequency are often available only for a relatively short time-span and we had to backdate a number of series. To do this we relied mostly on the database by Fagan et al. (2001) (hereafter Area-Wide Model (AWM) database). This was the case of the Eurostat national account series in volume, which only start in 1991 and therefore had to be chained backwards. Therefore, some caution is needed when analyzing the data in the beginning of the sample, not only due to methodological considerations but also because country data availability becomes scarcer as we move back in time.

Regarding national accounts deflators, the Eurostat series were chain linked with ECB data, which corrects for exchange rate variations among member countries in the period prior to 1999. Data on compensation per employee are published by the ECB. The series starts in the first quarter of 1991, and was chain-linked with data from the AWM database. The euro area capacity utilization series is published by the European Commission and is available since 1985. For the earlier periods we constructed a *proxy* for the euro area aggregate based on available data for the member countries. The M1 monetary aggregate series is published by the ECB. The short-term interest rate series used is the three-month Euribor provided by *Bloomberg* and for periods before 1999 we used data from the AWM database.

One important novelty in this paper is the use of a quarterly series for hours worked in the euro area. As there is no official series of average hours worked in the euro area we had to construct a new series. To do this we used country data on average hours worked per person

[2] The data ser includes all the 12 countries participating in the euro area in 2006.

in employment published by the OECD. However, and as mentioned by the OECD, there are significant differences in the sources and coverage of national data, implying that comparisons of the level of average hours worked across countries are probably not suitable. Therefore, we aggregated the quarterly rates of change of country series based on the euro area structure of employment (across countries) to get an index of average hours worked in the euro area.[3] Finally, we obtain per capita hours by multiplying average hours per persons in employment by total employment and then dividing by working age population.

All variables are in logarithms, except for the short-term interest rate. Inflation is measured as quarterly changes in the logarithm of the GDP deflator.

3.2 Low-Frequency Properties of the Variables

A proper identification of the monetary policy and technology shocks requires all variables in the VAR to be stationary. Looking at figure 1 it is apparent that while some variables seem clearly stationary, others are less so. Among the variables that do not look stationary, some seem to be driven by deterministic trends.

In order to ascertain as accurately as possible the low-frequency properties of the data, we carry out a series of formal tests in pursuit of sources of nonstationarity in the data. The strategy we put in place consists of three main steps. First, we apply a battery of unit root tests to distinguish the stationary from the nonstationary variables in the sample. Second, we test for the presence of linear or quadratic deterministic trends among the variables labeled as nonstationary. Lastly, whenever significant, the deterministic trends are removed and the unit root tests re-run[4]. After the de-trending process, the variables that remain nonstationary according to the unit root tests enter the VAR in first-differences.

On a first passage, we subject each variable to three distinct unit root tests, namely the Augmented Dickey-Fuller (ADF), the Phillips-Perron (PP), the Elliott, Rothenberg, and Stock (ERS), and Ng and Perron (N-P) tests which have unit root as the null hypothesis, and the Kwiatkowski, Phillips, Schmidt and Shin (1992) test (KPSS), which has stationarity as the null hypothesis. The results of these tests are summarized in table 1[5].

As seen in the table, on the basis of the results of the ERS and N-P tests all of the variables could be non-stationary. Looking at all the tests, there is strong evidence that inflation, the interest rate and money velocity are non-stationary variables. The results also point overwhelmingly to non-stationarity in the cases of hours per capita and investment to output ratio. The less clear cut cases pertain to productivity growth, consumption to output ratio, capacity utilization and productivity to real wage ratio. In the case of productivity growth, the results of both the ADF and the PP tests point to a rejection of the null of non-stationarity while the results of the KPSS test point to a rejection of the null of stationarity. Given that the ADF and PP tests have low power, we view these results as constituting strong evidence of the stationarity of this series. In this respect, it should also be noted that the KPSS test has severe size-distortions for highly persistent, albeit stationary series[6]. Therefore we take productivity growth to be a

[3] The behaviour of the constructed series seems reasonable, namely when compared with the one of the ECB's estimate of euro area average hours worked published in the October 2004 Monthly Bulletin. The ECB used annual data from the European Labor Force Survey, which is available only at an annual frequency and for a relatively short time span.

[4] Since the presence of deterministic trends affects the power of the unit root tests, and the presence of unit roots tampers inference on the significance of deterministic trends by altering the sampling distribution of the relevant test-statistics, we also tried to apply the unit root tests after looking for the presence of deterministic trends. Although not reported here, inverting the testing sequence did not alter the outcome regarding the low-frequency properties of all our variables.

[5] The reported tests include a constant, but no time trend.

[6] This problem is well documented in Kwiatkowski et al. (1992) and Caner and Kilian (2001).

Variable	Test-Statistic				
	Null: Non-stationarity				Null: Stationarity
	ADF	PP	ERS	N-P	KPSS
Productivity growth	-3.38**	-14.52***	26.75	-0.91	1.22***
Hours	-2.95*	-2.41	95.31	0.25	1.18***
Inflation	-0.70	-1.27	21.65	-0.62	1.20***
Consumption/GDP	-2.65*	-2.69*	6.73	-4.35	0.26
Investment/GDP	-2.64*	-2.42	10.67	-2.81	0.61**
Capacity Utilization	-2.78*	-2.89**	17.04	-1.81	0.15
Productivity/Real Wage	-1.37	-3.23**	29.23	-1.05	0.31
Interest Rate	-1.82	-1.84	3.65	-7.36	0.78***
Money Velocity	-1.81	-1.81	70.13	-0.34	0.71**

*,**,***, denote rejection of the null at the 10%, 5%, 1% significance level, respectively.

Table 1: Unit Root Tests

Variable	Zivot-Andrews Test	
	ADF-statistic	**Break Date**
Hours	-3.76	1984Q4
Inflation	-4.14*	1996Q2
Investment/GDP	-4.43**	1982Q3
Productivity/Real Wage	-4.61**	1974Q1
Interest Rate	-4.19*	1980Q2
Money Velocity	-3.14	1981Q4

*,**,***, denote rejection of the null at the 10%, 5%, 1% significance level, respectively.

Table 2: Tests of Unit Root vs Broken Trend Stationarity

stationary series. We also opt for stationarity in the case of the consumption to output ratio and of capital utilization as there is some evidence to reject the null of non-stationarity in the cases of the ADF and PP tests and no evidence to reject the null of stationarity in the KPSS test. The variable productivity to real wage ratio remains a borderline case.

We then gather the potentially nonstationary variables and search for the presence of significant deterministic components. Since none, among the group of potentially nonstationary variables, seems to have a linear trend along the whole sample, we resort to the procedure proposed by Zivot and Andrews (1992) that enables to test the null of a unit root against the alternative of stationarity around a broken linear trend. In particular, this procedure estimates the (single) break date that maximizes the evidence against the null of nonstationarity, computes an ADF-type test-statistic and provides the relevant critical values[7]. The outcomes of the application of the Zivot and Andrews test to the group of nonstationary variables are summarized in table 2.

Based on the results of table 2, we take the variables inflation, investment to output ratio, productivity to real wage ratio and the interest rate to be stationary around a broken linear

[7] As suggested by Zivot and Andrews (1992), the break date is searched between the 15^{th} and the 85^{th} percentile of the sample.

trend. As regards hours and money velocity, it seems that a broken linear trend is not enough to induce the stationarity of these variables. However, in the case of money velocity, graphical inspection of the series suggests that a quadratic trend might be a better characterization of the deterministic components at play. In fact, the inclusion of a quadratic trend is found to be highly significant and to make detrended money velocity stationary[8].

To sum up, to estimate the VAR we use productivity growth, consumption to output ratio and capital utilization as in their original series. We estimate and remove broken linear trends from inflation, investment to output ratio, productivity to real wage ratio and the interest rate and a quadratic trend from money velocity. As for per capita hours, we consider it to be a non-stationary variable and therefore include it into the VAR in first-differences.

4 Benchmark specification

In this section, we report the responses of our set of macroeconomic variables to a monetary policy shock and a neutral technology shock. In the following description of the results, we concentrate on the first 20 quarters after the occurrence of each shock.

4.1 Impulse responses to a monetary policy shock

The responses of the variables to the monetary policy shock are shown in figure 2. In this figure the solid lines depict point estimates and the grey areas their respective 95% confidence bands[9]. The responses of all variables are measured in percentages, except the interest rate, which is measured in basis points. There are several interesting features worth highlighting from this figure. First, the one-standard deviation monetary policy shock is estimated to be around 40 basis points which is somewhat higher than the estimate of 30 basis points obtained by Peersman and Smets (2003). The fall in interest rates is quite persistent, lasting over one year. Money growth and velocity react contemporaneously to the monetary policy shock, a feature that stems directly from our identifying assumptions. Not surprisingly, the expansionary monetary shock induces a liquidity effect that fades away in tandem with the nominal interest rate. Second, there is a hump-shaped response of output, consumption, investment, hours per capita and capacity utilization, with the peak effect occurring one and a half to two years after the shock. As expected, the response of investment is quantitatively stronger than that of consumption. Third, the response of inflation is characterized by a fall on impact followed by a rebound that takes approximately two years to reach its peak[10]. Surprisingly, the very short run reaction of real wages is to decline, in spite of inflation falling at the same time. That effect is reversed eventually so that real wages' response goes into positive territory.

4.2 Neutral technology shock

The responses of the variables to the neutral technology shock are shown in figure 3. Several conclusions are worth underlining from this figure. First, the impact of a one-standard deviation positive technology shock is to generate a steady increase in output that reaches roughly 0.8% after 20 quarters. There is also a positive permanent effect on real wages, consumption and investment, as expected. Second, the response of inflation to the technology shock is mostly

[8] The ADF test-statistic for money velocity after removing the estimated quadratic trend is -3.75, thereby implying the rejection of the null of unit root at the 5% significance level.

[9] These bands were computed by bootstrap simulation with 2.000 draws.

[10] An initial negative response of inflation to an expansionary policy shock has been dubbed as the 'price puzzle'. This effect has also been identified in several empirical studies for the US Altig et al. (2005).

contemporaneous and the largest response occurs on impact. However, this response is not statistically different from zero. Third, per capita hours endure what seems to be a permanent fall, a result similar to the one reported by Galí (2004) for the euro area[11]. This outcome means that positive technology shocks generate a lasting drop in the amount of labour input used in the economy. Together with the empirical observation that hours worked are procyclical this result raises doubts regarding the validity of the RBC paradigm. In fact, if technology shocks were the main drivers of business cycles then our VAR findings would imply a negative relation between hours worked and output growth and not the positive one seen in the data. Our results using VARs with model based restrictions are in contrast with those of Peersman and Straub (2004) who, using an identification procedure based on sign-restrictions, find that hours worked (or employment) rise following a positive technology shock. Nevertheless, they are very much in line with those of Fernald (2007) who shows that after properly accounting for the non-stationarity in the hours series for the US, hours fall after a positive technology shock. In this context, it is important to note that, in line with the conclusions reported in Christiano, Eichenbaum and Vigfusson (2004), the response of hours to a technology shock would also change substantially if hours worked were found to be stationary.

5 Robustness tests

This section tests the robustness of the impulse responses obtained with the benchmark VAR specification with respect to different sample periods and also to different definitions of some variables.

The sample period tests consist of estimating the impulse responses recursively for different samples. Two exercises were conducted. In a first exercise, the start of the sample is progressively increased while maintaining the end of the sample unchanged. In a second exercise, the end of the sample is progressively decreased while the start of the sample is kept unaltered.

The impulse responses for the monetary policy shock and the technology shock estimated with a sample recursively starting in the first quarter of 1970 up to the last quarter of 1979 and ending in the last quarter of 2006 are shown in figures 4 and 5, respectively. Starting with the monetary policy shock, as seen in figure 4, the qualitative responses of the variables seem broadly to follow the patterns of the benchmark model. As for the technology shock, the results show that, at least in a qualitative sense, in most cases the impulse responses are robust to the different starting points. There seems to be some uncertainty regarding the magnitude of the responses of output, and consumption but not about their sign. In the case of investment, the very short-term response is negative in some sub-samples but becomes undoubtedly positive in the medium to long-term. Finally, the responses of money velocity and the interest rate appear to be somewhat erratic, which is consistent with the full-sample result that they are not significantly different from zero.

Figure 6 shows the impulse responses of the monetary policy shock estimated with a sample starting in the first quarter of 1970 and with a decreasing end of sample (backwards from the last quarter of 2006 to the fourth quarter of 1997). From figure 6, it can be concluded that the impulse responses of all of the variables are quite robust to changes in the end of sample as they appear to be rather stable. As for the technology shock (see figure 7), there are some signs of instability in the magnitude of the response of hours, but the responses always point towards a decline following a positive technology shock. Another variable which shows somewhat erratic responses is capital utilization. As with the case of the increasing start of the sample, the responses of money velocity and the interest rate to a technology shock are again those that

[11] This is so in spite of Galí (2004) using employment rather than hours as the measure of labor input.

display stronger variability in the different sub-samples.

As regard the sensitivity of the results to different variable specifications, we test the robustness of the results to the use of alternative measures of the labour input and monetary aggregates[12].

As regards the labour measure, we redo our VAR analysis considering the first-difference of log per capita employment[13]. It turns out that the qualitative pattern of the impulse responses to technology and monetary policy shocks using this alternative measure of the labour input remains broadly unchanged.

As for the monetary aggregate, replacing the measure of money M1 by the broader measure M3 does not impart any significant change to the pattern of the effects of the monetary policy shock on all variables, except money growth. In fact, the liquidity effect following a negative interest rate shock disappears when M3 is used instead of M1 (i.e. money growth drops at the time of the expansionary interest rate shock). Nevertheless, M3 growth in the following quarters increases. This different reaction of M3 compared to M1 may be related to the fact that the share of interest remunerated components in M3 is rather large when compared to M1. If these components are more reactive to interest rate movements than those in M1, then M3 growth is likely to temporarily fall when there is an unexpected decline in the short-term interest rate.

6 Variance Decomposition

We now assess the contribution of the monetary policy and technology shocks to the forecast error variance of the variables included in our VARs. Table 3 summarizes the results. Before describing the evidence obtained, it is useful to explain some patterns of the results that stem directly from the identification strategy. First, the contribution of the monetary policy shock to the fluctuations of the real variables placed before the interest rate in the VAR list in equation (1) is zero on impact (i.e. in period 1). That follows from our timing assumption that those variables are sticky in the short-term, reacting to monetary policy shocks only with a lag. Second, the contribution of the technology shock to the fluctuations in output increases as we move forward in the horizon, a feature that stems from our identifying assumption that these shocks are the sole source of the unit root in labour productivity.

From table 3 it is worth highlighting that technology shocks play a significant role in explaining the fluctuations of output, hours worked and real wages. This result, which is predicted by the RBC paradigm, contradicts that of Galí (1999) for the U.S., but is consistent with the evidenced gathered by Altig et al. (2005) for the U.S. and Peersman and Straub (2004) for the euro area. Therefore, while the evidence presented in the previous section does not support some of the RBC propositions, we still find that technology shocks have quite an important role in explaining business cycle fluctuations.

As for the monetary policy shock, we find its contribution to be relative unimportant in explaining the fluctuations of all variables, except those of the interest rate, as expected. That is also the thrust of the results in Altig et al. (2005) and Peersman and Straub (2004).

[12] Notice that changing the definition of the labor input requires re-specifying productivity and nominal wage variables accordingly.

[13] This latter measure is stationarised using a broken trend with a break date of 1974Q1. As indicated by the Zivot-Andrews test, the resulting variable appears to be stationary.

	Variance Due to:							
	Technology Shock				Monetary Policy Shock			
Quarters	1	5	10	20	1	5	10	20
Output	32.4	76.3	88.6	93.4	0.0	2.1	1.3	0.4
Hours	31.2	27.7	29.2	39.0	0.0	2.8	5.1	2.1
Inflation	9.4	8.7	8.6	12.0	0.0	7.5	7.5	8.9
Capacity Utilization	0.0	0.2	0.2	7.9	0.0	8.2	17.0	14.9
Consumption	23.4	71.8	83.8	90.4	0.0	1.8	0.7	0.2
Investment	10.1	30.9	51.7	65.1	0.0	7.5	11.3	6.9
Real Wage	48.7	52.9	56.4	67.9	0.0	0.9	1.3	0.6
Interest Rate	0.2	0.9	0.9	1.0	86.2	61.1	39.7	33.5
Velocity	1.1	1.0	0.9	2.1	2.4	11.8	8.3	5.8
Money Growth	0.1	7.6	7.3	8.0	3.3	4.4	6.5	6.3

Table 3: Variance decomposition

7 Conclusions

This paper characterized the responses of the main euro area macroeconomic aggregates to monetary policy shocks and neutral technology shocks. Most of our results are qualitatively in line with those found in the VAR literature for the euro area. Our characterization benefited from the introduction of a novel series for hours worked in the euro area thereby constituting a further contribution to the ongoing debate on the behaviour of hours after technology shocks. We argued that the main conclusions in Galí (1999, 2004), that hours worked fall after a positive technology shock, also apply to the euro area. Further, we have found a substantial degree of robustness of the results, both to the sample period and to the definitions of the variables,

Assessing whether changes to the VAR specification and the quality of the data substantively affect our conclusions remains an open issue. These qualifications and caveats call for more research on the quest for the set of shocks, frictions and policies that, embedded in a general equilibrium framework, explains the dynamics of real and nominal variables in the euro area business cycle.

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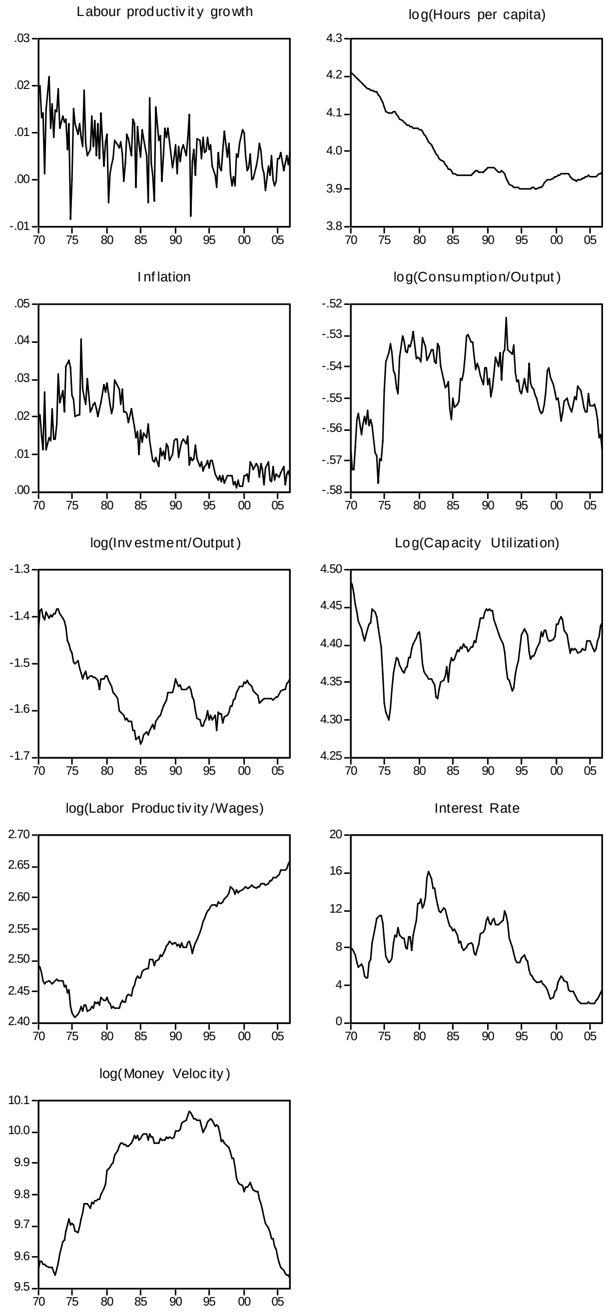

Figure 1: Raw data

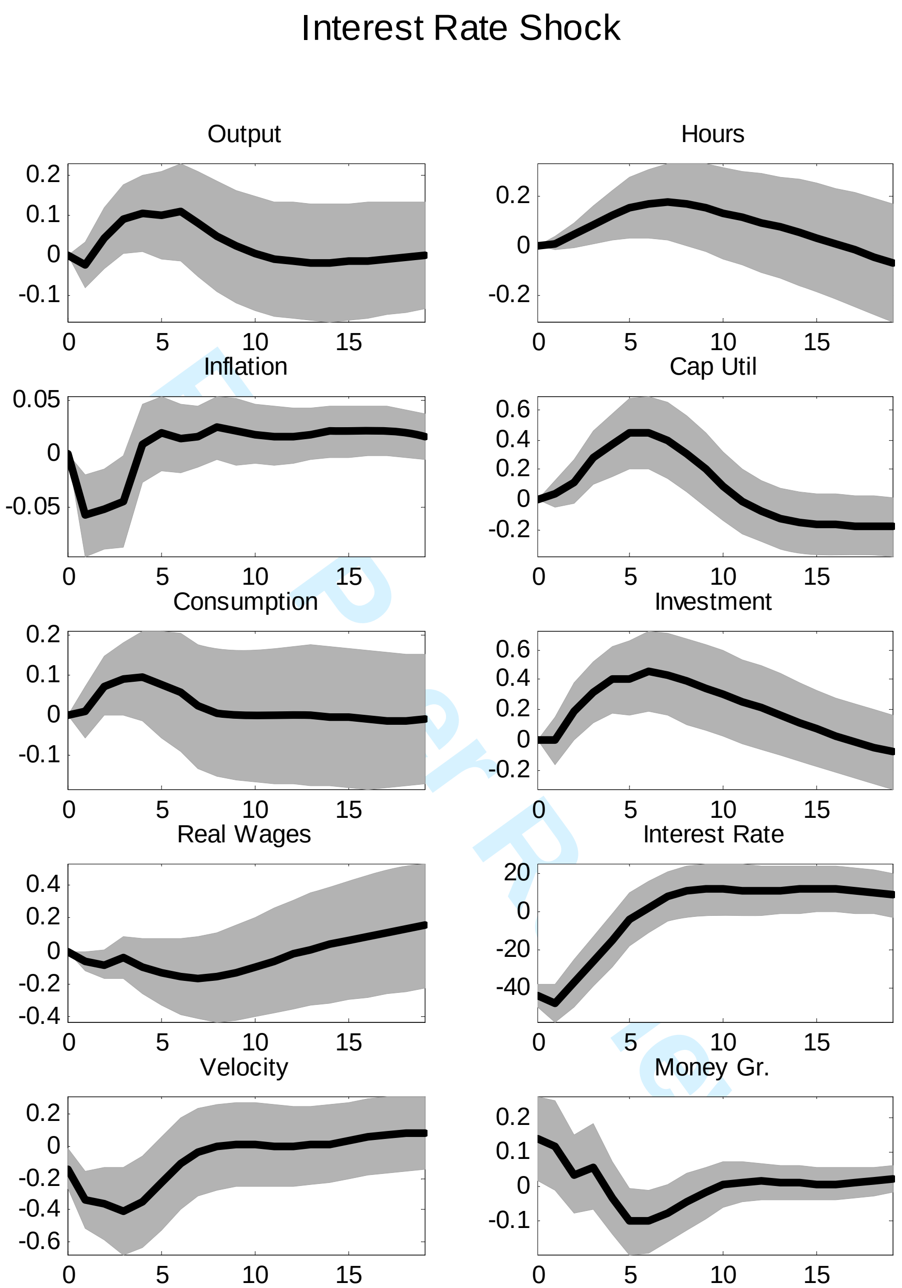

Figure 2: Impulse responses to a negative monetary policy shock.

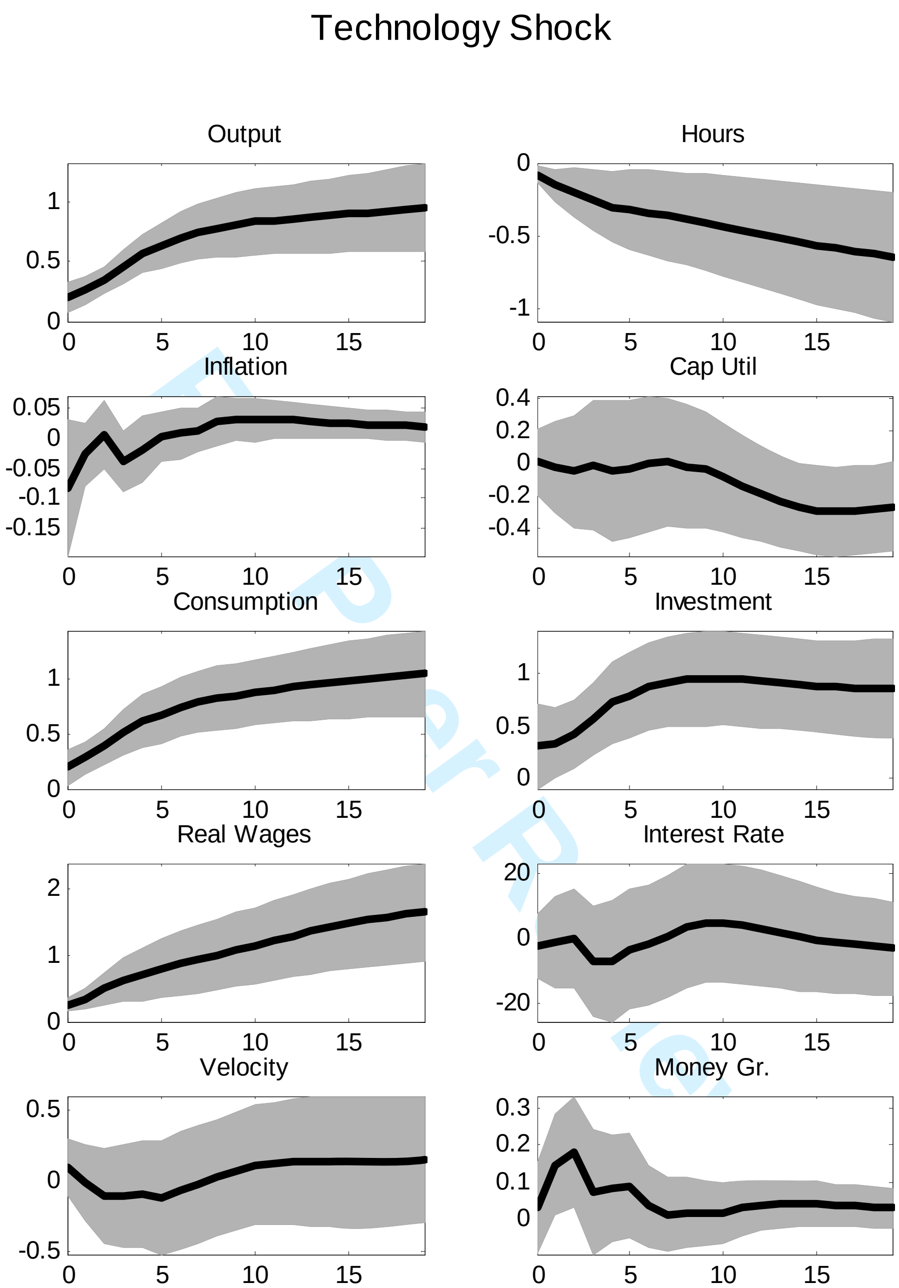

Figure 3: Impulse responses to a positive technology shock.

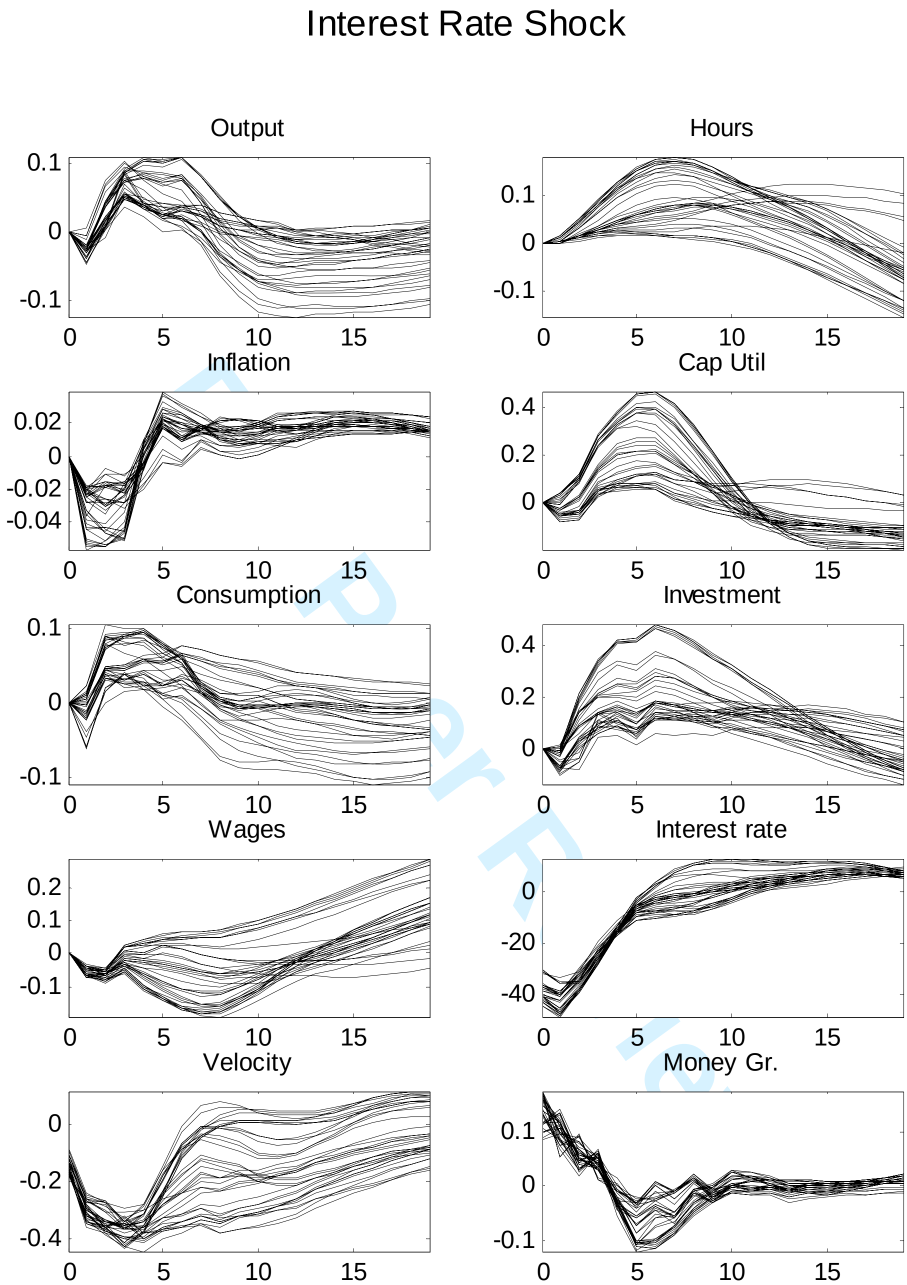

Figure 4: Impulse responses to a negative monetary policy shock with increasing start of the sample. Start: 1970Q2:1979Q4; end: 2006Q4.

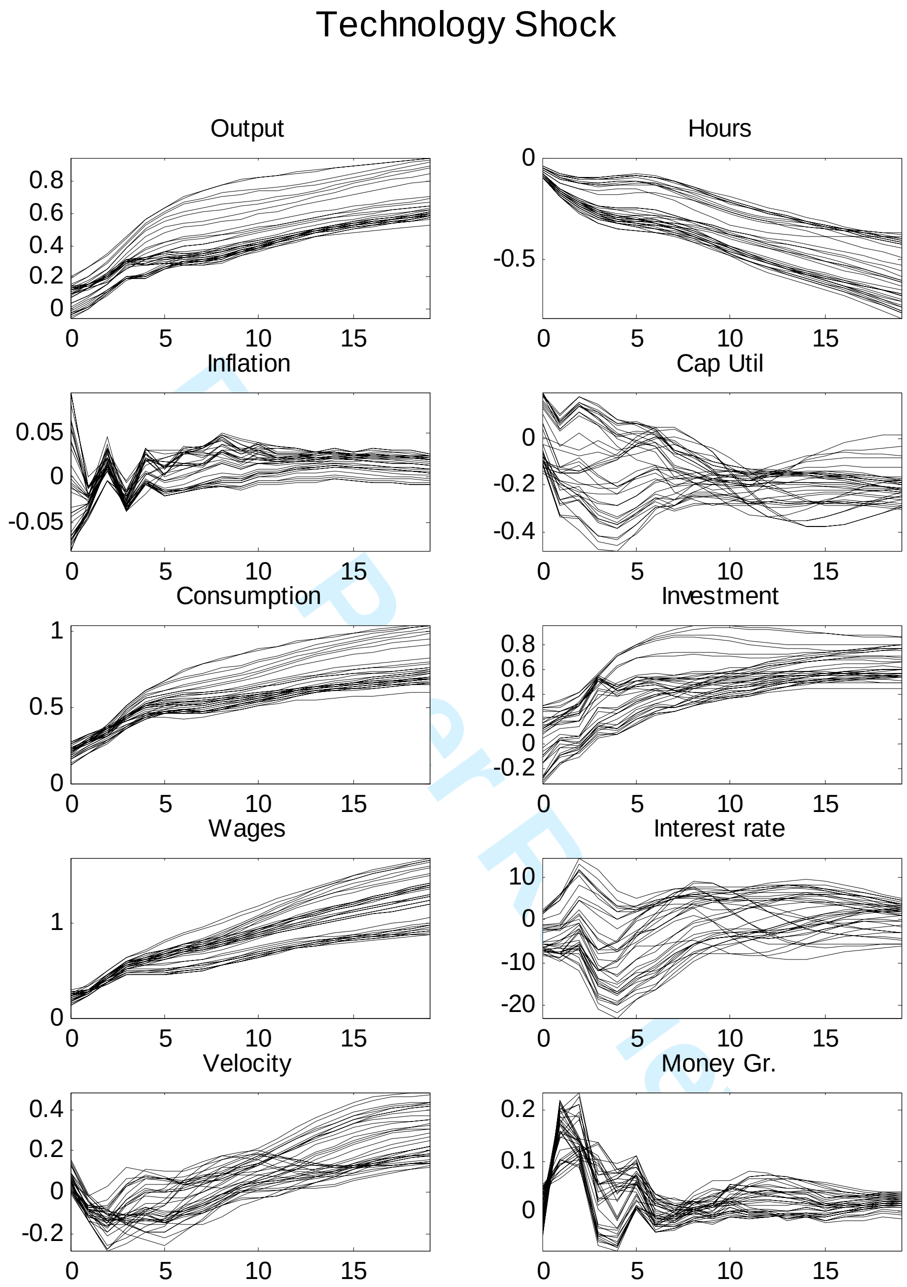

Figure 5: Impulse responses to a neutral technology shock with increasing start of the sample. Start: 1970Q2:1979Q4; end: 2006Q4.

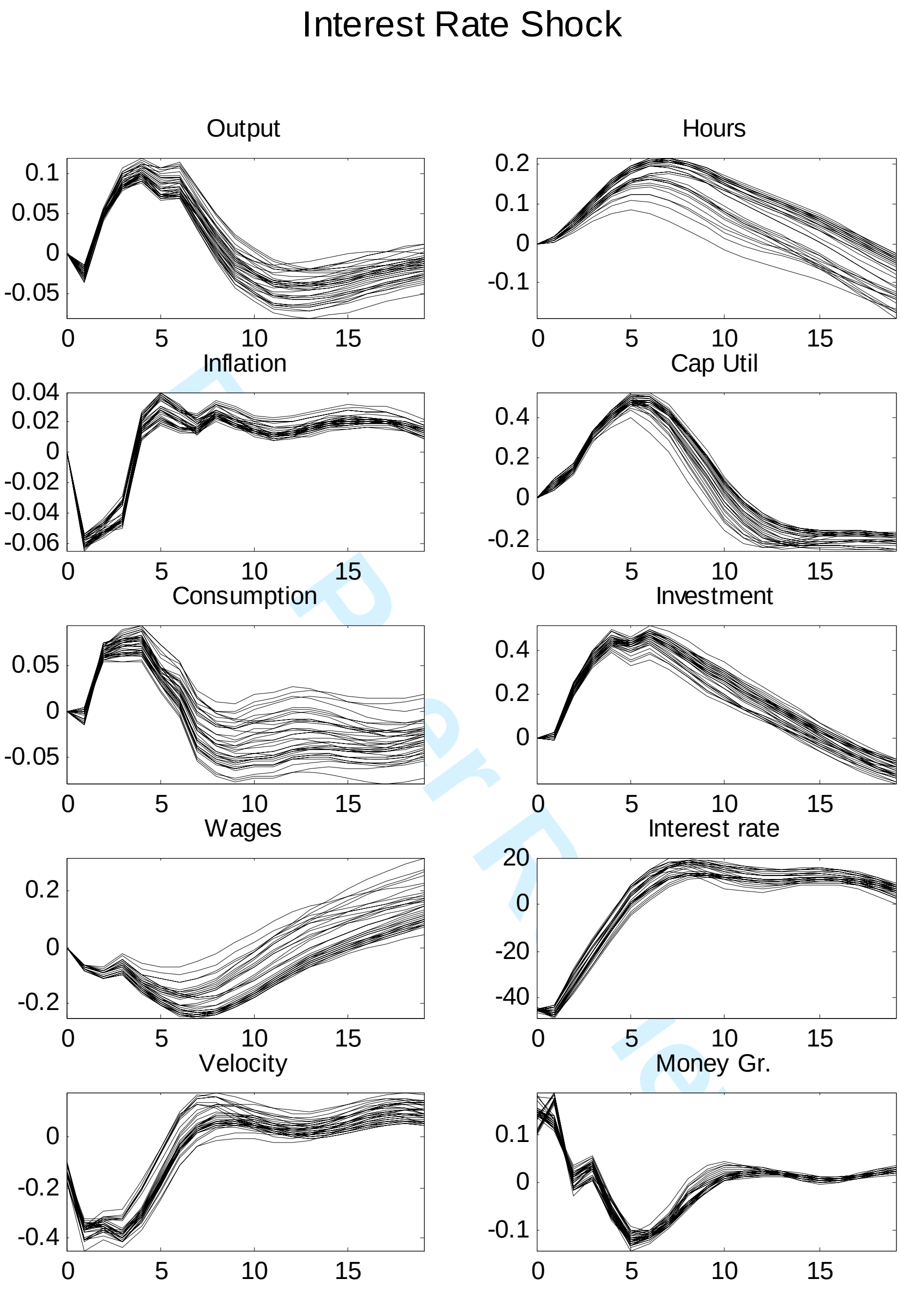

Figure 6: Impulse responses to a negative monetary policy shock with decreasing end of the sample. Start: 1970Q1; end: 1997Q1-2006Q4.

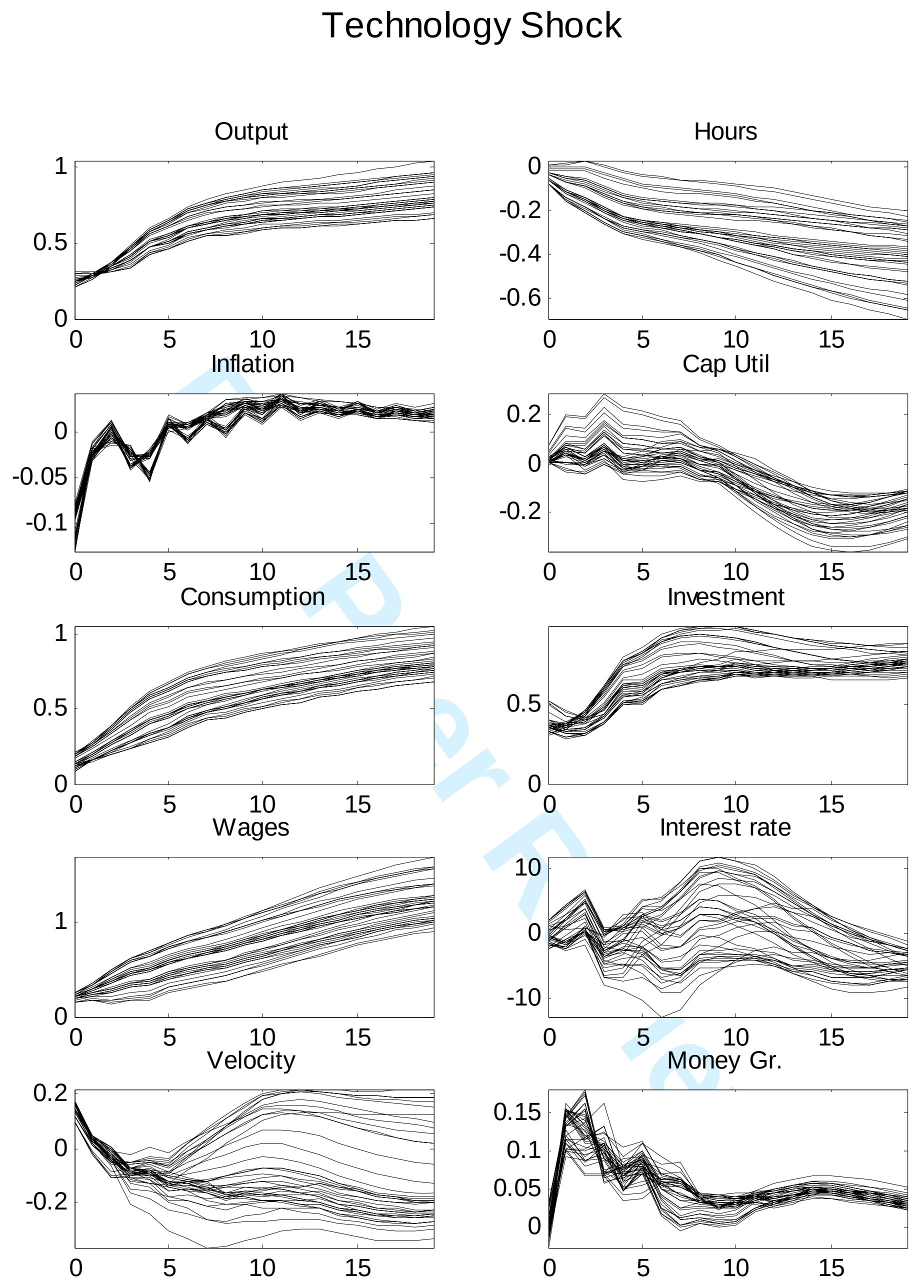

Figure 7: Impulse responses to a neutral technology shock with decreasing end of the sample. Start: 1970Q1; end: 1997Q1-2006Q4.